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Infants and iCubs: Applying Developmental Psychology to Robot Shaping

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Abstract

Achieving sentient robots will not only require understanding of neuro-models that generate *behaviour from structure*, but will also need research into the role of *development*, that is how *behaviour determines structure.* We emphasise infant sensory-motor development and identify an explicit framework that can guide the design of similar developmental processes in robotics. We show how human development sequences can be mapped on to robotic platforms and how constraints on perception and action can be utilised so that staged behaviour and learning may take place. The growth of increasing competence can be managed by this method of *unsupervised shaping by constraints.*

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Keywords: Autonomous Robots; Unsupervised Shaping; Developmental Learning

1. Introduction

The golden vision for robotics research is to discover the principles that determine how truly autonomous, cognitive robots might be created. No existing robots can approach anywhere near this goal, mainly because of our very considerable gaps in understanding. To appreciate the enormity of the task, consider what is expected of a truly autonomous agent. They must be capable of continuously developing within their environment; they must be motivated to explore and learn new abilities; and they must be able to adapt and build upon these abilities. They must also be sentient in that they possess sensory awareness; that is, they experience sensations in terms of their own body, and this includes models of themselves and others so that they can understand their own agency as a distinct entity in the environment as well as viewing and dealing with others as similar agencies.

The *Embodiment* movement in robotics has made much progress in shifting the focus away from programming and AI methods by recognising the central influence of the body and its morphological properties on the development of cognition. This includes all the sensory-motor subsystems as the essential substrate upon which all cognitive functions are built. This *grounding,* in the body and its basic sensory-motor facilities, is a key principle that appears to have fundamental significance.

In current robotics research neuroscience supplies structural data for brain models that generate behaviour. However, such approaches do not cover the *growth processes* that create and influence those structures. We work from a different premise and are exploring the *developmental* aspects of behaviour. While neuro-models generate *behaviour from structure,* we are exploring how *behaviour determines structure.* We argue that research on developmental learning for

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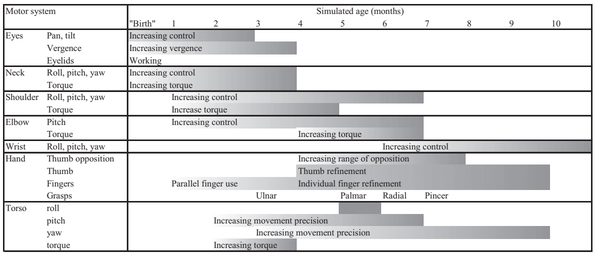

Figure 1. Partial motor development sequence for the iCub.

Developmental stage	"Age"	Eyes			Neck				Torso				Saturation criteria	Observed behaviour
	(months)	tilt	version	vergence	pitch	roll	yaw	torque	roll	pitch	yaw	torque		
1 Eye saccade	0	d	d										Low occurance of unknown saccades	Eye saccades to fixate on stimuli
2 Vergence	0			d									Low occurance of unknown vergence movements	Both eyes converge onto a single stimuli
3 Neck movements	0				d	d	d	d					Low occurence of unknown movements	Neck roll pitch and yaw movements
4 Eye & head visual search	0	d	d	d	d	d	d	d					Low occurance of unknown combinations of movements	Head and eyes move together to fixate on a stimulus
5 Torso pitch	2									d		d	Low occurence of unknown movements	Torso bends foraward and backward
6 Eye, head & torso pitch visual search	2	d	d	d	d	d	d	d		d		d	Low occurance of unknown combinations of movements	Fixations incorporate bending movements at the waist
7 Torso pitch & yaw	3									d	d	d	Low occurence of unknown movements	Torso bends forwards, backwards and sideways at waist
8 Eye, head & torso pitch & roll visual search	3	x	x	d	d	d	d	d		d	d	d	Low occurance of unknown combinations of movements	Fixations incorporate bending and leaning movements
9 Eye, head & torso pitch & roll visual search improvement	4	x	x	x	x	x	x	x		d	d	x	Few improvements in eye and neck movements	Looking whilst bending and leaning
10 Torso roll, pitch & yaw	5								x	d	d	x	Low occurence of unknown movements	Torso bends, leans and rotates at waist
11 Full body visual search	5	x	x	x	x	x	x	x	x	d	d	x	Low occurance of unknown combinations of movements	Looking with whole body movement
12 Improvement of torso pitch	7	x	x	x	x	x	x	x	x	x	d	x	Few improvements in torso pitch	Less jerky bending movement whilst looking
13 Improvement of torso yaw	10	x	x	x	x	x	x	x	x	x	x	x	Few improvements in torso yaw	Smoother body rotation whilst looking

Figure 2. Example constraint chart indicating dependencies and sequences.

robots must take better account of *infant development* and should draw from the large psychological, biological and medical literature.

In child development, shaping, also known as scaffolding, is an approach to the problem of learning complex abilities from primitive beginnings. Shaping refers to the refinement and mastery of a sequence of skills as they become progressively harder: in essence, shaping is a staged process of development [1]. Shaping is normally described as a supervised learning technique, but during very early infancy there is little scope for proper supervision. We have developed a method of *unsuper-vised shaping* and designed mechanisms whereby the effect of shaping is achieved using simple intrinsic motivation instead of externally imposed goal structures. In this approach, called LCAS, (Lift-Constraint, Act, Saturate) [2], the gradual learning of sensory and motor skills is achieved through the modulating influence of a dynamic constraint network.

2. The importance of constraints

Human infants are restricted in their development by a wide range of constraints. These include cognitive, sensory-motor, anatomical and hardware properties of the agent, as well as general maturational limitations and environmental effects. By reducing complexity or bandwidth such constraints restrict the task space and effectively act to shape learning, limiting interactions and reducing the perceived complexity of the environment [1,3]. These constraints are then gradually eased or lifted, allowing the infant to advance into a new stage of development [3]. By identifying stages in infant development, we have derived sets of constraints that will shape similar development in a robot.

3. Development in the iCub robot

From the infant development literature we have extracted the timings and level of development of sensor and motor systems that are applicable to our iCub robot. For example, neck control develops over the first three months after birth, whereas wrist control does not appear to start until the 6th month. As an illustration, an abstraction of the motor development sequence is shown in Fig. 1. From such data, a constraint table can be created: this shows the relationship between different constraints and when they are relevant in the developmental sequence, see Fig. 2. We use associative learning to build mappings and hence learn the correlation between sensor and motor spaces. Learning of mappings is driven by novelty, with the robot repeating actions that result in novel changes in sensory spaces. Eventually, the robot will have investigated the available space, and learning will saturate. A measure of habituation triggers the removal or relaxation of a constraint, resulting in a stage transition or improvement of resolution. The learning cycle then begins again. A detailed description of the constraints releasing framework can be found in [4] and [2]. See [5] for more on cross-modal coordination.

4. Human-Robot interaction

Intrinsic activity actually simplifies the motivation mechanisms in that goals are created, not given, and thus removes the need for explicit goals. Of course, any goals that we desire for the system must be achieved entirely through shaping by user interaction. Our work on the Rossi project is examining affordances and their grounding in experience. See [6] for further details.

5. Summary

The combination of the *Embodied Intelligence* perspective on the importance of sensory-motor structures and the *Developmental Robotics* emphasis on the grounding of very early experience provides a powerful multi-disciplinary paradigm for research into autonomy and cognitive growth. We believe that knowledge of the finer patterns of development and the associated constraints will provide an understanding of robot shaping that will have wide applicability for robotics research. Our research programme is working towards full scale demonstrations of autonomous cognitive growth on an iCub humanoid robot.

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References

[1] J. Bruner, Acts of Meaning, Harvard University Press, Cambridge, MA, 1990.
[2] M. Lee, Q. Meng, F. Chao, Staged competence learning in developmental robotics, Adaptive Behaviour 15 (3) (2007) 241–255.
[3] J. Rutkowska, Scaling up sensorimotor systems: Constraints from human infancy, Adaptive Behaviour 2 (1994) 349–373.
[4] M. Lee, Q. Meng, F. Chao, Developmental learning for autonomous robots, Robotics and Autonomous Systems 55 (9) (2007) 750–759.
[5] M. Hulse, S. McBride, M. Lee, Fast learning mapping schemes for robotic hand-eye coordination, Cognitive Computation 2 (1) (2010) 1–16.
[6] M. Hulse, S. McBride, J. Law, M. Lee, Integration of active vision and reaching from a developmental robotics perspective, IEEE Transactions on Autonomous Mental Development 4 (2) (2010) 355–367.